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U.S. Army Research Institute
for the Behavioral and Social Sciences

Research Report 1528

Effects of the Advanced Map Interpretation and Terrain Analysis Course on Contour-Level Navigation Performance

Dudley J. Terrell
Anacapa Sciences, Incorporated

June 1989

U.S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

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EDGAR M. JOHNSON **Technical Director**	**JON W. BLADES** **COL, IN** **Commanding**

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Technical review by

Betty J. Angell
Charles A. Gainer
Gabriel P. Intano
Ronald J. Lofaro
Gena M. Pedroni

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

For this report, researchers evaluated the effectiveness of the Advanced Map Interpretation and Terrain Analysis Course (MITAC) and compared two strategies of error remediation in computer-based training. Forty-one OH-58 student pilots were given an inflight contour-level navigation pretest at the beginning of the Basic Combat Skills (BCS) course. Two experimental groups, with 14 subjects per group, received navigation training with the Advanced MITAC in addition to the standard BCS training. The two groups differed only in the manner in which Advanced MITAC errors were remediated. For one group, errors were followed by a computer presentation of the correct answer and a brief explanation of the navigation strategy that would have produced the correct answer (i.e., computer-remediated). For the other group, errors were followed by a requirement to work the navigation problem again (i.e., self-remediated). A control group of 13 subjects received only the standard BCS training. At the end of the BCS course, a significantly larger proportion of experimental subjects than control subjects performed perfectly on an inflight navigation posttest.
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Of the experimental subjects who did not perform perfectly, those in the self-remediated group tended to stray slightly farther and to spend more time off course than those in the computer-remediated group. Supplemental training with the Advanced MITAC enhanced inflight navigation performance, and computer-generated error remediation was slightly more beneficial than self-generated error remediation.

Research Report 1528

Effects of the Advanced Map Interpretation and Terrain Analysis Course on Contour-Level Navigation Performance

Dudley J. Terrell
Anacapa Sciences, Incorporated

ARI Aviation R & D Activity
Charles A. Gainer, Chief

Training Research Laboratory
Jack H. Hiller, Director

U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

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FOREWORD

The Army Research Institute for the Behavioral and Social Sciences (ARI) performs research and development to improve training effectiveness and to contribute to training readiness. Of special interest are research and development programs that apply computers and other advanced technologies to the development of part-task trainers and training strategies. Research that identifies the most effective strategies for designing computer-based trainers and training programs will enhance the development and procurement of specific part-task training systems required by the Army training community.

This report summarizes efforts to develop computer-based methods of training map interpretation and terrain analysis skills for geographic orientation. Research is reported that evaluates the effectiveness of a prototype computer-based, interactive device for training low altitude navigation. Future research that investigates further the dynamics of computer/trainee interaction will be applied to the development of instructional strategies and decision guidelines for computer-based trainers.

This work was conducted within the Training Research Laboratory program under Research Task 3309, entitled "Techniques for Tactical Flight Training." The Aviation Research and Development Activity at Fort Rucker, Alabama, was responsible for execution of the work. The Scout Company of the Aviation Training Brigade requested assistance in September 1987 to employ an experimental navigation training package for the Aeroscout 93B and the Undergraduate OH-58 Aviator Candidate. This work was initially developed in direct support to the U.S. Army Aviation Center (USAANVC) under a 15-hour block of instruction entitled "Map Interpretation and Terrain Analysis Course (MITAC)." Work is continuing on training methods that can be used to improve the effectiveness of the combat aviator with the lowest cost media.

This work was briefed to the 1-14th Battalion Commander, B and E Company Commanders, and the Directorate of Flight Training at Fort Rucker. The MITAC material was integrated into the flightline portion of the Initial Entry Rotary Wing (IERW) training program to remediate students who were having difficulty with navigation. The material also was provided to the HS-2 Strike Rescue Squadron of the Jacksonville Naval Air Station through a cooperative effort at the Aviation Center.

The MITAC has been accepted among the instructor pilots for operational flight training but has not received full endorsement as an academic instrument.

EDGAR M. JOHNSON
Technical Director

ACKNOWLEDGMENTS

Mr. Gary Coker, Anacapa Sciences, Inc., wrote the computer programs for the Advanced MITAC. CPT Scott Ferderber, U.S. Army, designed the navigation test routes and coordinated the instructor and student pilot activities during the inflight navigation tests.

EFFECTS OF THE ADVANCED MAP INTERPRETATION AND TERRAIN ANALYSIS COURSE ON CONTOUR-LEVEL NAVIGATION PERFORMANCE

EXECUTIVE SUMMARY

Requirement:

This research was conducted to evaluate the training effectiveness of the Advanced Map Interpretation and Terrain Analysis Course (MITAC) and to compare the effects of two methods of computer-based error remediation on inflight navigation performance.

Procedure:

Forty-one OH-58 student pilots were given an inflight contour-level navigation pretest at the beginning of the Basic Combat Skills (BCS) course. Two experimental groups, with 14 subjects per group, received navigation training with the Advanced MITAC in addition to the standard BCS training. The two groups differed only in the manner in which Advanced MITAC errors were remediated. For one group, errors were followed by a computer presentation of the correct answer and a brief explanation of the navigation strategy that would have produced the correct answer (i.e., computer-remediated). For the other group, errors were followed by a requirement to work the navigation problem again (i.e., self-remediated). A control group of 13 subjects received only the standard BCS training. At the end of the BCS course, all subjects were administered an inflight contour-level navigation posttest.

Findings:

A significantly larger proportion of experimental subjects than control subjects performed perfectly on an inflight navigation posttest. Of the experimental subjects who did not perform perfectly, those in the self-remediated group tended to stray farther and to spend more time off course than those in the computer-remediated group. Advanced MITAC training has no effect on the number of times that subjects were assisted by an instructor pilot (IP) on the posttest, nor did it affect the distributions of final grades for Terrain Flight Navigation, Map Interpretation, or the final BCS checkride.

Utilization of Findings:

The findings suggest that Advanced MITAC training is effective for teaching contour-level navigation skills to helicopter pilots. Designers of training programs that require aviators to learn how to navigate at contour levels should consider including an Advanced MITAC part-task trainer in their repertoire of training resources.

The findings also suggest that computer-generated error remediation may be more effective than self-generated error remediation. However, these findings require confirmation through additional research. The Advanced MITAC provides a suitable vehicle for conducting additional research to investigate computer-based feedback and remediation and other computer-based training strategies.

EFFECTS OF THE ADVANCED MAP INTERPRETATION AND TERRAIN ANALYSIS COURSE ON CONTOUR-LEVEL NAVIGATION PERFORMANCE

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EFFECTS OF THE ADVANCED MAP INTERPRETATION
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CONTOUR-LEVEL NAVIGATION PERFORMANCE

INTRODUCTION

In the modern battlefield, Army aviators will be forced to fly at extremely low altitudes to avoid detection by enemy electronic sensors and to increase their probability of survival. Three types of flight operations are conducted in the low altitude regime: low altitude flight at a constant indicated altitude, low altitude flight at a constant altitude above the contour of the terrain (contour flight), and very low altitude flight with constantly changing altitude, airspeed, and heading in an attempt to remain masked by the terrain or other land and cultural features (nap-of-the-earth flight).

At these low altitudes, aviators must navigate primarily by pilotage--the visual association of ground features with their map portrayal. Research has found that low altitude navigation is very difficult to perform and that traditional training programs designed to instruct pilotage have been ineffective (Fineberg, Meister, & Farrell, 1978). Therefore, the Army Research Institute Aviation Research and Development Activity (ARIARDA) is conducting research directed toward improving the effectiveness of low altitude navigation training programs.

One product of the ARIARDA research is the application of computer-based instructional technology during the development of navigation part-task trainers. This report describes (a) the development of the Map Interpretation and Terrain Analysis Course (MITAC) that was designed to instruct low altitude pilotage and (b) recent research that evaluated the effectiveness of the computer-based MITAC training.

Background

This section describes early research documenting the deficiencies in low altitude navigation training, traces the development of cinematic navigation exercises, and summarizes experiments investigating the effectiveness of those exercises. In earlier research, McGrath and Borden (1964) developed a cinematic method for evaluating navigation skill. Their system employed motion picture films of high speed, low altitude flights viewed on a rear projection screen. They noted that experienced Navy pilots performed poorly at following flight courses presented in this manner.

Wright and Parley (1971) noted several factors that contribute to the difficulty of navigating at very low altitudes. At higher altitudes, a pilot can spend more time attending to

activities inside the cockpit, such as reading instruments and studying maps. Because of the attention required to maintain obstacle clearance and the limited time that terrain features are in view, low altitude flight requires more vigilance outside the cockpit. Correlation of terrain features with map portrayals must be performed quickly, with most of the time being spent looking outside of the cockpit and very little time studying the map. Wright and Pauley suggested that skill in rapid map interpretation and terrain analysis may be developed through improvements in training. They recommended the development of cinematic map interpretation exercises as a means for improving the training.

Gainer and Sullivan (1976) also suggested that wide-angle, high resolution films of the nap-of-the-earth (NOE) environment could be used to meet a number of low altitude navigation training requirements. Combined with geographic orientation exercises, such films can demonstrate the impact of terrain and vegetation masking, oblique angles, and brief exposure times on the recognition of navigational checkpoints at very low altitudes. They noted that most Army pilots are limited to flight experience over only one or two types of terrain and further suggested that films be taken in a number of geographic regions varying in terrain, climate, and season.

McGrath (1976) reviewed reports of navigation performance research and concluded that, despite varying results from different experiments, "the percentage of sorties in which the crew experiences no problem of navigation and remains well oriented throughout the flight is exceedingly small" (p. 60). This conclusion is supported by the results of research in which rotary wing aviators with varying levels of flight experience flew experimental NOE navigation missions in UH-1 aircraft (Fineberg et al., 1978). The more experienced pilots controlled their aircraft better than the less experienced pilots. However, navigation performance was generally poor, and there was no relationship between flight experience and NOE navigation performance.

Clearly, Army aviators must be provided effective training to acquire the visual referencing skills required for precise and rapid navigation and geographic orientation at low altitudes. Increasing the number of flying hours would provide more training time, but it may be more economical to develop part-task trainers that display low altitude terrain features.

The MITAC was developed in 1976 to meet the requirement for a part-task trainer of low altitude navigation (McGrath, 1976). The original MITAC comprised numerous full motion sequence and still frame pictures of terrain features and map segments designed to teach low altitude navigation skills to helicopter pilots in a classroom setting. Subsequently, this course was redesigned from a group training format to an individual training format. Holman (1978a, 1978b) evaluated the effectiveness of this course and demonstrated that MITAC-trained student pilots and aerial observers navigated NOE at twice the speed and with one-third of

the errors committed by conventionally trained aviators. These exercises were upgraded subsequently into a videodisc format (Terrell & Miles, 1988). The videodisc course, called the Basic MITAC, is designed to teach the interpretation of map symbols for terrain relief, hydrography, vegetation, and cultural features.

Additional cinematic lessons were developed for use in operational units (Kelley, 1979; Miles & LaPointe, 1986). These Advanced MITAC lessons consist of films taken from the front window of a helicopter flying over various geographic regions (see Table 1). They provide sustainment training in map interpretation and terrain analysis for individual aviators in the operational units.

Problem

During the development of part-task training devices, it is important to test the effectiveness of the course content. Therefore, the training effectiveness of the Advanced MITAC film exercises must be examined. In addition, the utilization of computer technology in the development of part-task training requires systematic examination of strategies for presenting the course content to students. In other words, it is insufficient to establish that a training package effectively supplements traditional training. Effectiveness evaluations of computer-based training

Table 1

The Geographic Regions and Seasons of the Advanced MITAC Lessons

Lesson Number	Geographic Region	Season
1	Hodgenville, Kentucky	Summer
2	Hodgenville, Kentucky	Winter
3	Kingswood, Kentucky	Summer
4	Kingswood, Kentucky	Winter
5	Vine Grove, Kentucky	Summer
6	Vine Grove, Kentucky	Winter
7	Gleeson, Arizona	Summer
8	Fort Huachuca, Arizona	Summer
9	Fort Huachuca, Arizona	Summer
10	Boise, Idaho	Summer
11	Boise, Idaho	Summer
12	Lichtenfels, Germany	Spring
13	Uffenheim, Germany	Spring

programs also should identify the best strategies for presenting information to students. Subsequently, these empirically identified strategies can be incorporated during the development of other training programs.

The instructional strategies used to provide student-computer interactivity in part-task trainers should be examined experimentally. One example of interactivity is the manner in which student responses on the computer are reinforced or remediated. If a student responds correctly, what is the most effective method for reinforcing the developing skill? If a student responds incorrectly, what is the most effective method for remediating the skill or knowledge deficiency?

Objectives

This research was designed to evaluate the effectiveness of a navigation part-task trainer. The two specific objectives were to (a) evaluate the training effectiveness of the Advanced MITAC exercises, and (b) compare the effects of two methods of computer-based error remediation on inflight navigation performance.

METHOD

Subjects

The subjects for this research were 41 male student pilots whose rank ranged from Warrant Officer Candidate to Captain. All subjects were enrolled in the OH-58 Basic Combat Skills (BCS) course at the U.S. Army Aviation Center, Fort Rucker, Alabama.

Apparatus

Two Advanced MITAC systems were used. Each system comprised a Zenith microcomputer (Model No. ZWX-248-62), a Pioneer Laser-vision Player (Model No. LD-V6000A), a Sony Trinitron Color Video Monitor (Model No. PVM-1271Q), 7 videodiscs, and 13 laminated map plates (i.e., one for each exercise route). The systems were located in the flightline classrooms of the OH-58 BCS course, B Company, 1/14 Aviation Regiment. Inflight test data were recorded on laminated map plates for each test route.

Description of Advanced MITAC

Each Advanced MITAC lesson has three chapters. The first chapter is a preflight briefing that explains the map portrayal of the operations area. The second chapter presents a film taken from the front window of a helicopter flying a route at low altitude. At various markpoints in the film, the action stops and the student enters the map coordinate for that point. The computer calculates the distance between the student's coordinate and the correct coordinate (i.e., the error). If the distance is less than or equal to 200 meters, the student is permitted to continue to the next markpoint. If the distance is greater than 200 meters, a narrated review of the film is played from the last markpoint. After the review, the action continues until the next markpoint. Each route contains seven markpoints. At the end of the exercise, the computer displays the amount of error for each markpoint. The third chapter in each lesson is a narrated version of the Chapter 2 training film (i.e., the source of the review segments).

Pre-experimental Briefing of Instructor Pilots

Before the experiment began, the experimenter described the purpose of the research, the general experimental design, and the procedure for the inflight navigation performance evaluations to 17 instructor pilots (IPs). The IPs were instructed to locate the start point of the navigation test route and then to fly the aircraft according to navigation instructions provided by the subjects. The navigation lessons in the Basic Combat Skills program of instruction require that the student navigate to within 500

meters of checkpoints at contour-level altitudes. Therefore, the IPs were informed that a deviation of more than 500 meters from the prescribed test route would be counted as a navigation error. The IPs also were instructed that, if the aircraft deviated 2000 meters or more from the prescribed route, they should assist the subjects by (a) informing them of the aircraft's position on the map and (b) returning the aircraft to the point on the route where the error was initiated. Finally, the IPs were instructed to draw the actual path of flight on a laminated map plate depicting the prescribed route.

Procedure

Each subject participated in three successive phases of the research. The first phase consisted of the inflight navigation pretest. The second phase consisted of the navigation training. The third phase consisted of the inflight navigation posttest.

Phase 1: Inflight navigation pretest. On the first or second day of the BCS course, each subject was shown the two pretest routes on a map. Each route was approximately 20 km long, crossed approximately 13 streams or roads, and involved 5 turns of 90° or less. The IPs considered the two routes to be of equal difficulty. During the regular training for the day, the IP selected one of the two routes for the student to navigate. The student was told which route to navigate several minutes prior to reaching the start point of the route. Nineteen subjects navigated one route; 22 subjects navigated the other. An IP flew each aircraft at approximately 60 knots indicated airspeed (KIAS) and followed navigation instructions provided by the subject. Immediately following the flight, the IP drew the actual path of flight on a laminated map plate.

For each pretest flight, the experimenter compared the drawing of the actual path of flight with the drawing of the prescribed route and recorded four navigation performance measures:

- the number of navigation errors (i.e., the number of instances that the aircraft deviated more than 500 meters from the prescribed route);
- the maximum extent of each error (i.e., the distance between the prescribed route and the point at which the aircraft was farthest from the prescribed route);
- the length of each error (i.e., the actual distance flown while the aircraft was at least 500 meters from the prescribed route), and
- the number of times that the IP assisted the subject during the test flight.

Group assignment. Subjects were classified according to whether they made 0, 1, or 2 or more errors on the navigation pretest. An approximately equal number of subjects from each of these error categories was assigned to each of three training groups prior to beginning Phase 2. Two groups (14 subjects per group) trained with the Advanced MITAC in addition to the standard training in the BCS course. The two Advanced MITAC groups differed in the method of computer-based error remediation they received (see the Navigation Training Procedures section). The third group (13 subjects) received only the standard BCS training.

Phase 2: Navigation training. Each subject in both Advanced MITAC training groups performed six navigation exercises on the part-task trainer. Three of the exercises were filmed in Kentucky (Lessons 1, 3, and 5), one in Idaho (Lesson 10 or 11), one in Arizona (Lesson 7, 8, or 9), and one in Germany (Lesson 12). The sequence of exercises was neither controlled nor systematically manipulated. Subjects were told about the exercises available and were allowed to view them in any sequence. If a subject indicated no preferred sequence, to the extent possible, the experimenter selected a sequence that avoided replicating sequences selected by other subjects.

During the Advanced MITAC exercises, if a subject entered a coordinate that was more than 200 meters from the correct coordinate, one of two error remediation procedures occurred. For subjects in the Standard MITAC group, errors were followed by a presentation of the correct coordinate and a narrated review of the preceding film segment. The narration described useful checkpoints and strategies for geographic orientation during that portion of the film. The student then initiated the next segment of film and continued the exercise. For subjects in the Modified MITAC group, errors were followed by a silent replay of the film segment. Each subject was required to enter a coordinate that was within 200 meters of the correct coordinate before continuing to the next film segment. These subjects were not shown the correct coordinate, and they did not hear any film narration. Subjects in the No MITAC group were prohibited from viewing the Advanced MITAC lessons.

Phase 3: Inflight navigation posttest. One or two days before the end of the BCS course, each subject was shown the two posttest routes on a map. Each route was approximately 24 km long, crossed approximately 13 streams or roads, and involved 6 turns of 115° or less. The IPs considered the two routes to be of equal difficulty. During the regular training for the day, the IP selected one of the two routes for the student to navigate. The student was told which route to navigate several minutes prior to reaching the start point of the route. Twenty subjects navigated one route; 21 subjects navigated the other. An IP flew each aircraft at approximately 80 KIAS and followed navigation instructions provided by the subject. Immediately following the flight, the IP drew the actual path of flight on a laminated map plate.

For each posttest flight, the experimenter compared the drawing of the actual path of flight with the drawing of the prescribed route and recorded the same four navigation performance measures that were recorded during the pretest. After each subject finished the BCS course, the experimenter also recorded the final Terrain Flight Navigation Score, Map Interpretation Score, and Checkride Grade assigned by the subject's IP.

RESULTS

The distribution of scores for each dependent variable within each condition (i.e., Groups x Test) was analyzed for homogeneity of variance using Cochran's *C* test (Roscoe, 1975). There were no significant differences in variance between any two distributions. The distributions were then analyzed for skewness (Snedecor & Cochran, 1967). At least two distributions for each dependent variable were significantly skewed ($p < .05$). Although the variances are not significantly different from each other, the non-normality of the distributions limits the reliability of inferences based on parametric statistical tests such as the analysis of variance. Therefore, the data were analyzed with nonparametric statistics (Siegel, 1956). Because of the lower power of the nonparametric statistics and the small sample sizes, an alpha level of .10 was adopted as the criterion for statistical significance.

Number of Errors on Pretest and Posttest

Within each group, subjects were categorized according to whether they made 0, 1, or ≥2 errors on the pretest and on the posttest. Figure 1 shows the percentage of subjects in each category for each group. On the pretest, 54% of the subjects (overall) made 2 or more errors, while only 19% made 0 errors. There are no significant differences between the groups because of

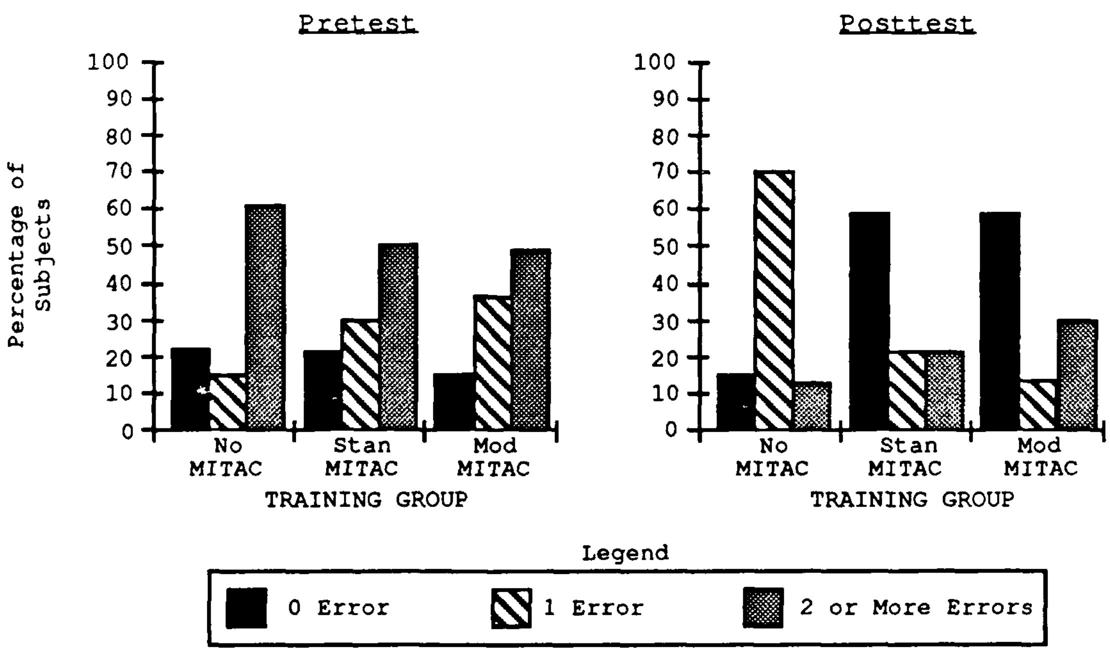

Figure 1. Percentage of subjects in each training group that made 0, 1, or ≥2 errors on the pretest and posttest.

the subject assignment procedure. On the posttest, 15% of the subjects in the No MITAC group made no errors, while 57% of the subjects in both the Standard and Modified MITAC groups made no errors. These differences between groups are significant, χ^2 (4, N=41) = 11.23, (p < .05).

Maximum Extent of Error on Pretest and Posttest

When an IP flew the aircraft more than 500 meters from the prescribed route, the subject was considered to be making a navigation error. The maximum extent of the error is the distance between the prescribed route and the point at which the aircraft was farthest from the prescribed route. Therefore, only those subjects who made errors on the pretest or posttest received scores for this dependent variable. Specifically, there were 10, 11, and 12 subjects in the No MITAC, Standard MITAC, and Modified MITAC groups, respectively, who made errors on the pretest. There were 11, 6, and 6 subjects in the No MITAC, Standard MITAC, and Modified MITAC groups, respectively, who made errors on the posttest. For each subject and each test flight, the maximum extent of each error was summed and divided by the number of errors to produce a composite score for this dependent variable (i.e., the mean maximum extent of error).

Figure 2 shows the distribution of the composite scores for each group on the pretest and posttest. A Mann-Whitney U test showed no significant differences between the distribution of composite scores for any two groups on the pretest, confirming the effectiveness of the subject assignment procedure. However, there are significant differences between the posttest distribution of composite scores for the Modified MITAC group and the No MITAC group, U = 15.0, p < .10, and for the Modified MITAC group and the Standard MITAC group, U = 9.0, p < .10. Subjects in the Modified MITAC group who made errors on the posttest made more extensive errors than did the subjects in the Standard MITAC or No MITAC groups. That is, the Modified MITAC subjects tended to stray farther from the prescribed route during their errors than did the Standard MITAC or No MITAC subjects.

Length of Error on Pretest and Posttest

The length of error is the actual distance flown while an aircraft was at least 500 meters from the prescribed route. Again, only those subjects who made errors on the pretest or posttest received scores for this dependent variable. For each subject and each test flight, the length of each error was summed and divided by the number of errors to produce a composite score for this dependent variable (i.e., the mean length of error).

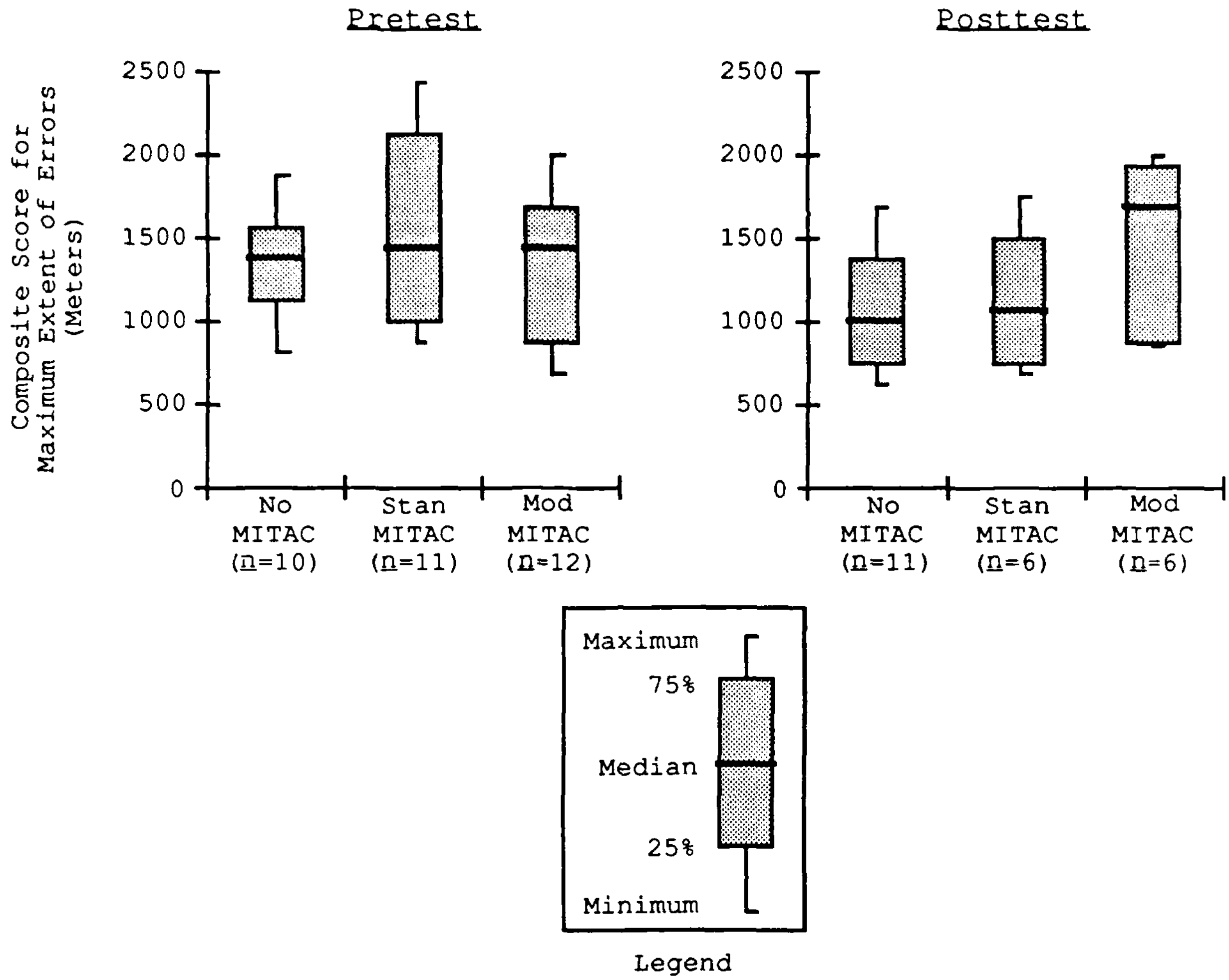

Figure 2. Distributions of pretest and posttest composite scores for Maximum Extent of Error.

Figure 3 shows the distribution of the composite scores for each group on the pretest and posttest. A Mann-Whitney $\underline{U}$ test showed no significant differences between the distribution of composite scores for any two groups on the pretest. However, there is a significant difference between the distribution of composite scores for the Modified MITAC group and the Standard MITAC group on the posttest, $\underline{U} = 9.5$, $\underline{p} < .10$. Subjects in the Modified MITAC group who made errors on the posttest made errors longer in duration than did the subjects in the Standard MITAC group. That is, the Modified MITAC subjects tended to fly farther while off-course than did the Standard MITAC subjects.

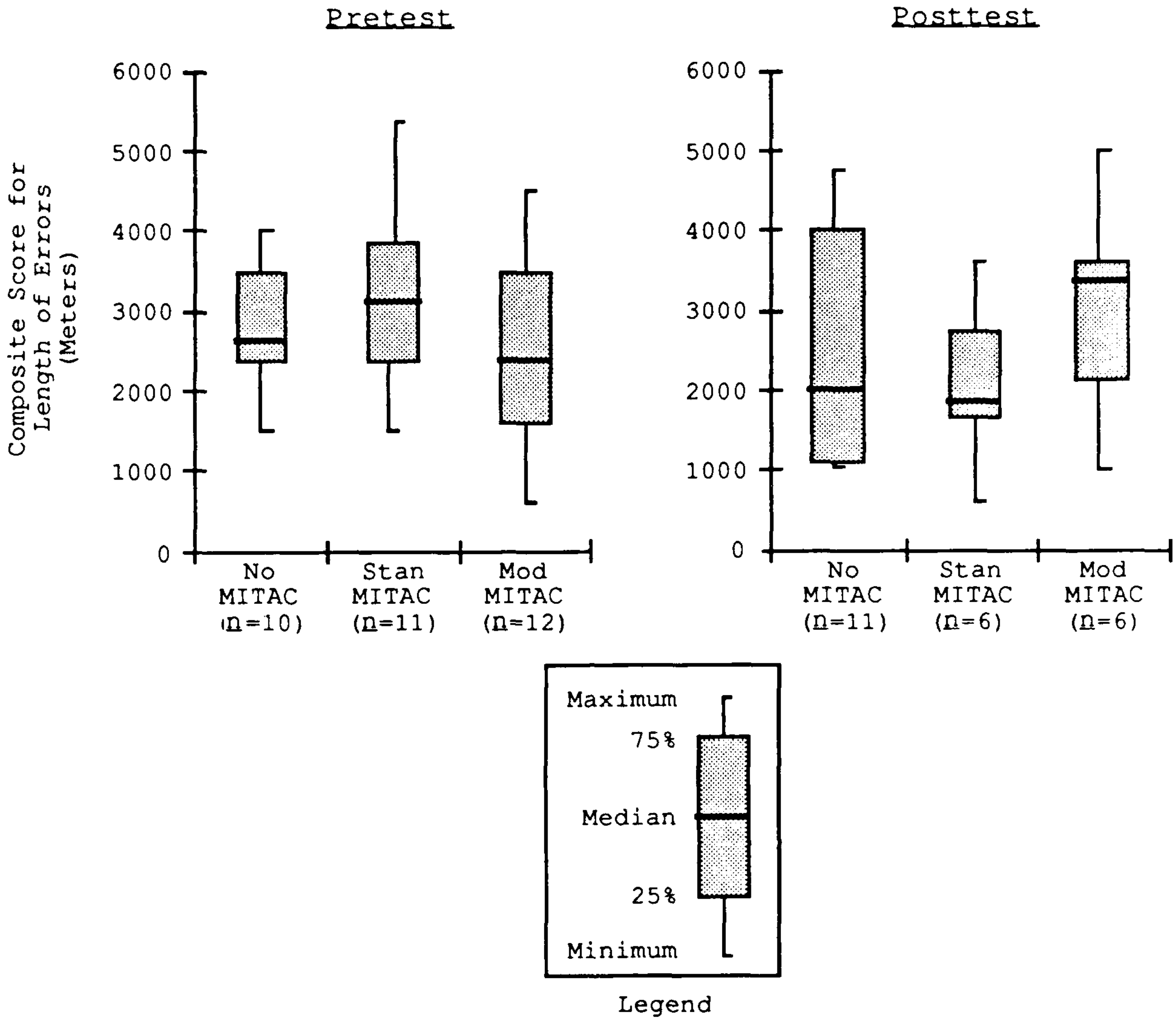

Figure 3. Distributions of pretest and posttest composite scores for Length of Error.

Number of IP Assists on Pretest and Posttest

Within each group, subjects were categorized according to whether they were assisted 0, 1, or 2 or more times on the pretest and on the posttest. Figure 4 shows the percentage of subjects in each category for each group. The differences between the groups are not significant.

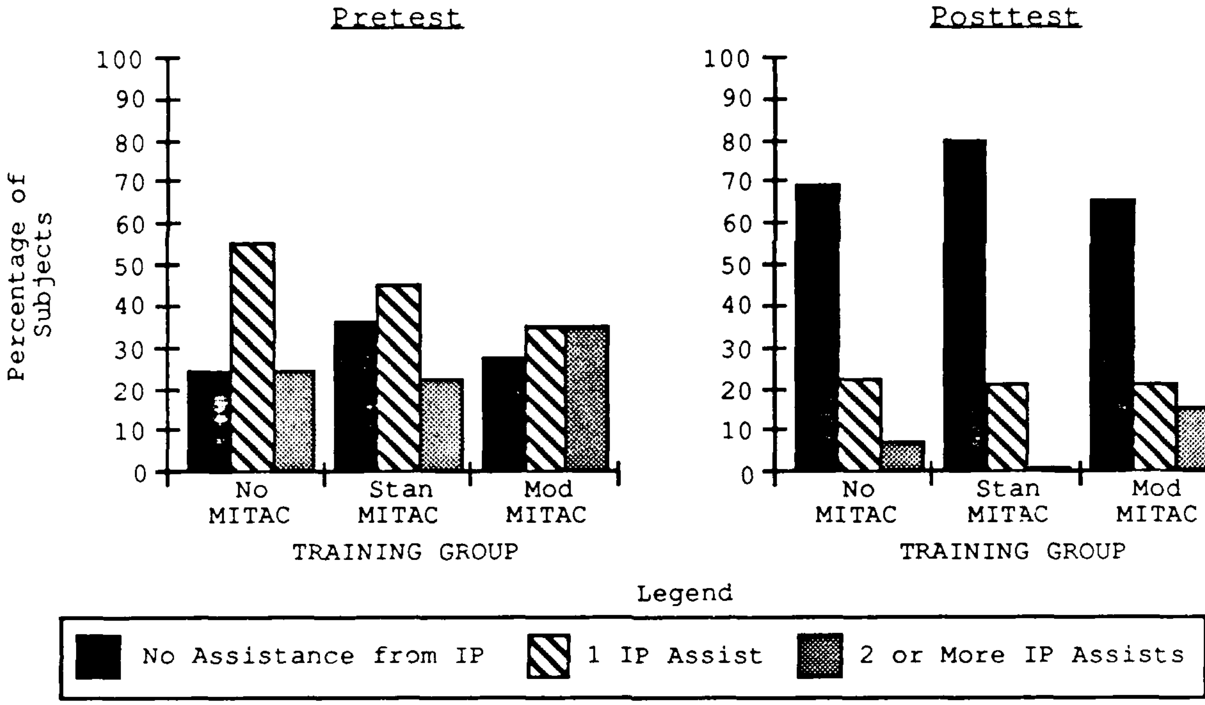

Figure 4. Percentage of subjects in each training group receiving 0, 1, or ≥2 instances of assistance from an IP on the pretest and posttest.

Final Grades in Basic Combat Skills Course

Figure 5 shows the distribution of final grades for Terrain Flight Navigation, Map Interpretation, and the Final Checkride for each training group. There were no significant differences between the groups for any of these dependent variables.

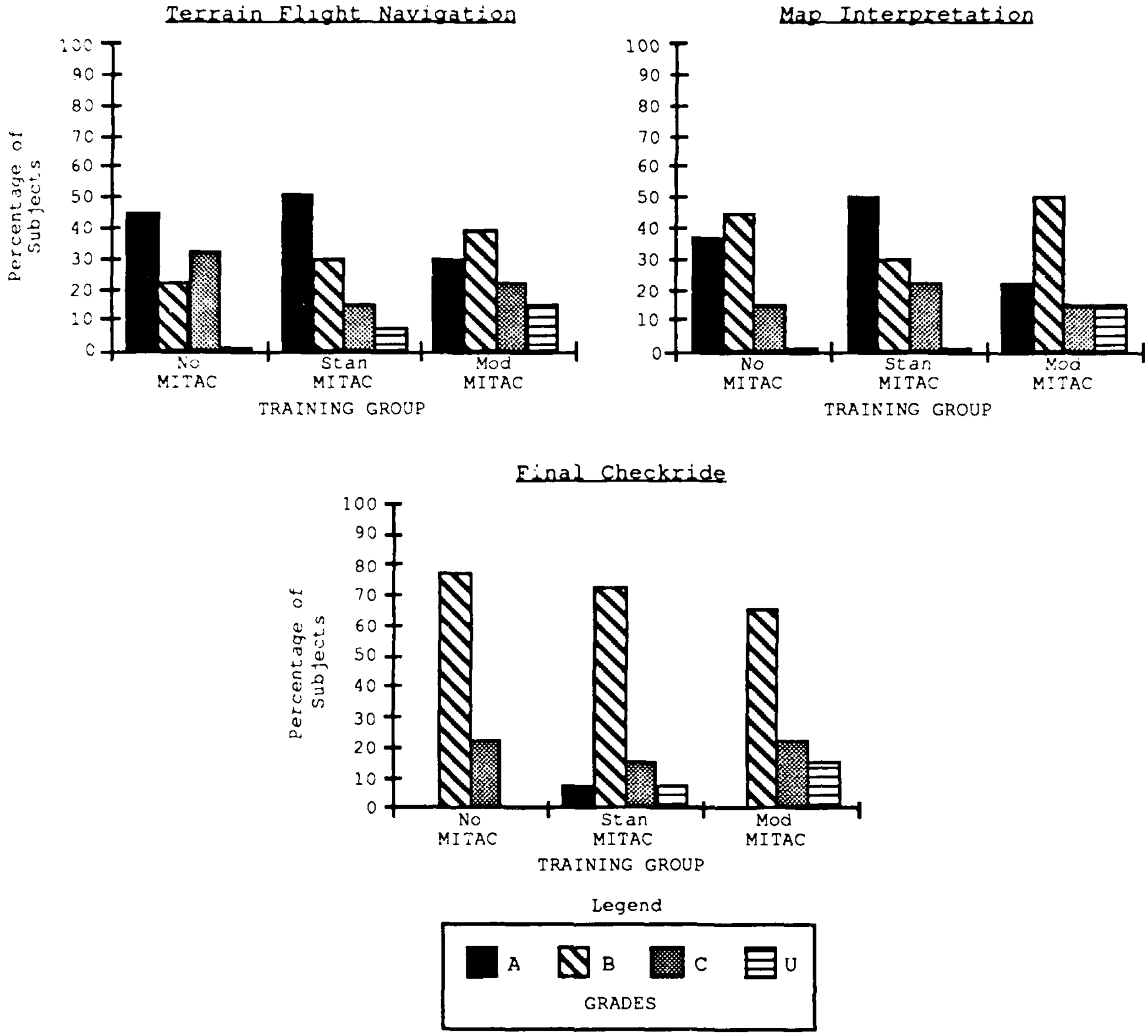

Figure 5. Percentage of subjects in each group with final grades of A, B, C, or U on Terrain Flight Navigation, Map Interpretation, and Final Checkride.

DISCUSSION

Advanced MITAC Training Effectiveness

Advanced MITAC training tended to reduce the number of inflight navigation errors, as evidenced by the finding that more MITAC subjects than control subjects performed perfectly on the posttest (Figure 1). One conclusion that may be drawn from this result is that Advanced MITAC training is effective for contour-level navigation performance.

The results do not provide information on the amount of training required. Each Advanced MITAC subject viewed six navigation lessons. The six lessons were sufficient to produce the effect observed here (i.e., reduction of posttest navigation errors). However, fewer lessons may produce the same effect, or more lessons may produce a greater effect.

Other results do not support this conclusion. Specifically, Advanced MITAC training had no effect on the number of times that students were assisted by an IP on the posttest, nor did it affect the distributions of final grades for Terrain Flight Navigation, Map Interpretation, or the Final Checkride (Figures 4 and 5). Assistance during the inflight navigation test was provided at the IP's discretion. Although the IPs were instructed about when to assist the subjects, the test data show that these instructions were not followed rigorously. Some IPs provided assistance before subjects were 2000 meters from the prescribed course; some provided assistance when subjects were farther than 2000 meters from the prescribed course. Likewise, the grades for Terrain Flight Navigation, Map Interpretation, and the Final Checkride were assigned by the IPs and probably were based on more skills than those trained in the geographic orientation exercises of the Advanced MITAC. Subjective assessments of the entire set of skills may not reflect adequately the effects of part-task training on a subset of those skills.

Computer-based Error Remediation

More MITAC subjects than control subjects performed perfectly on the posttest. However, of the subjects who made errors on the posttest, those in the Modified MITAC group tended to stray slightly farther and to spend more time off course than those in the Standard MITAC or No MITAC groups (Figures 2 and 3). A tentative conclusion drawn from these results is that computer-based trainers should be designed to remediate errors by presenting correct answers and explanations of how the correct answers can be derived. This conclusion is considered tentative for three reasons. First, it is supported by a level of statistical significance ($\alpha = .10$) that is less conservative than is used conventionally in parametric statistical analyses. Second, only six subjects in each of the MITAC groups made errors on the

posttest, and conclusions about the distribution of composite scores were drawn from this small sample of observations. Third, without assessing the sensitivity and accuracy of the measurement procedure, the reliability and validity of this finding is uncertain.

Nevertheless, these results suggest that the narration presented in the standard remediation procedure is a crucial variable contributing to the efficacy of the Advanced MITAC. The narration describes navigational checkpoints and strategies for geographic orientation and may have been sufficient to attenuate the extent and length of inflight navigation errors committed by subjects in the Standard MITAC group. Not only were subjects in the Modified MITAC group denied the opportunity to hear the narration, they were required to work the navigation problem again in the absence of a remedial narrative. These subjects may have developed ineffective geographic orientation strategies that transferred to the inflight navigation test.

Future Research Directions

The results of this experiment suggest several directions for future research. If the Advanced MITAC is to be used as a vehicle for research in computer-based training strategies, a reliable and valid measure of navigation performance needs to be developed. The reliability and validity of the inflight navigation performance measurement procedure used in the present experiment should be established.

Future research should continue to investigate error remediation procedures in computer-based training systems. The effects of the remedial narrative and the repetition of incorrectly answered problems were confounded in this experiment. Each of these variables should be examined separately.

Research also should be conducted to evaluate the relative effectiveness of various Advanced MITAC training options. For example, the effects of film speed, geographic region, sequence of regions, and number of lessons should be examined. Future research also should evaluate the effectiveness of the Advanced MITAC as a skill sustainment trainer for operational aviators. The effectiveness of the Advanced MITAC for skill sustainment training could be evaluated in operational Army aviation units and in various Army Reserve and National Guard units. The results of such research can be used to support prescribed training with the Advanced MITAC.

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